Height, income, and nutrition in the Netherlands

Jacobs, Jan; Tassenaar, Vincent

Height, income, and nutrition in the Netherlands: the second half of the 19th century

Jan Jacobs* and Vincent Tassenaar†

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Abstract

This paper explores the relationship between height and its explanatory variables, explicitly paying attention to dynamics involved in the velocity of growth. We establish that the relationship is characterized by a changing lag pattern. We try to illustrate this with recently published data on the nineteenth century for the Netherlands. We find some evidence for changing lag patterns in the relationship between height and some measures of income and nutrition.

Keywords: height, income, nutrition, 19th century, the Netherlands
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*. Department of Economics, University of Groningen, P.O. Box 800, NL-9700 AV Groningen, the Netherlands [j.p.a.m.jacobs@eco.rug.nl].

†. Department of Economic and Social History, Faculty of Arts, University of Groningen, P.O. Box 716, 9700 AS Groningen, the Netherlands [p.g.tassenaar@let.rug.nl].

1. Introduction

In the field of anthropometric history stature as a measure of standard of living attracts a lot of attention, see for example the overview of Steckel (1995) and the references therein. It is well-understood that heights are influenced by labour intensity, morbidity and nutrition; improvements in dietary intake, public sanitation, and medical technology play a role too (see *e.g.* Tanner 1981, Komlos 1989, and Floud *et al.* 1990).

This paper explores the relation between height and two of its explanatory variables, income and nutrition. The relationship between height and these explanatory variables has been studied quite extensively. An early contribution is Brinkman *et al.* (1988). Other examples are Coll (1998), Craig and Weiss (1998) and Haines (1998) in the collection of Komlos and Baten (1998), Mosk (1996) and the recent papers of Baten (2000) and Baten and Murray (2000). Attained height is a function of its determinants during the years of growth. So, lags enter the empirical model. In our opinion the issue of dynamics has not yet been dealt with convincingly. All empirical studies adopt a fixed lag scheme for the determinants of height, *i.e.* assume that the velocity curve of growth does not change over time. However there is ample evidence from medicine that the shape of the velocity curve of growth changes over time (Ljung *et al.* 1974; Eveleth and Tanner 1990; Wit *et al.* 1999; Fredriks *et al.* 2000).

We will derive a dynamic model of height starting from the identity that the measured heights are the sum of the height increments of the years from birth onwards. The only assumption we adopt is that height increments of a given year are influenced by 'environmental' circumstances, like income or nutrition, of that year. The resulting econometric model has a lag pattern that may change over time. Unfortunately, this model cannot be estimated and tested with aggregate data in which we have only one observation on height for each period. Ideally, we need information on the complete growth profile, like *e.g.* the Stuttgart schoolboys sample described in Komlos *et al.* (1992).

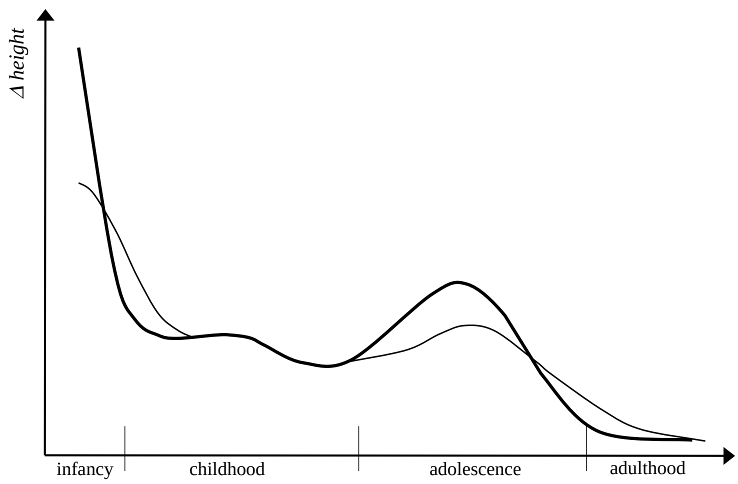
Therefore, rather than estimating an econometric model of height we illustrate the change in the lag pattern in an indirect way by means of bivariate correlation analysis. To avoid spurious correlation between trended series, we follow the lead of Woitek (2003) and calculate cycle components (*i.e.*, deviations from trend) of recently published series on 19th century height, income and nutrition in the Netherlands. Whereas Woitek uses spectral analysis to investigate cycle components, we apply more conventional correlation statistics to bring to the fore the evolving dynamic relations between height and a few explanatory variables. 3D-plots of correlations coefficients between the cycle components of height and the (lagged) cycle components in GDP per capita and nutrition over a moving thirty-one-year window reveal the change in the lag pattern. Appendix A briefly discusses the impact of a third measure, smallpox, on height.

The remainder of the paper is structured as follows. The next section presents the velocity of growth and cites some evidence from the literature why this curve is not time-invariant. Section 3 derives our empirical model of height. Section 4 describes the method we use to illustrate the changing lag pattern in the relationship between height and income and nutrition measures. Section 5 presents the data we use in our empirical illustration. Section 6 shows and discusses our empirical results. Section 7 concludes.

2. The velocity curve of growth

Two periods of intense activity characterize the growth process following birth (Tanner 1989). The change of height is greatest during infancy, falls sharply, and then declines irregularly into the childhood years. During adolescence velocity rises sharply to a peak that equals approximately one-half of the velocity during infancy, then declines rapidly and reaches zero in adulthood. The thick line in Figure 1 represents a stylized velocity curve, *i.e.*, the derivative of the growth curve.

Figure 1: A stylized velocity curve (thick line) and catch-up (solid line)



Source: Tanner (1989)

The height of an individual reflects the interaction of genetic and environmental influences during the process of growth. If a particular stimulus is lacking at a time when it is essential for the child, times known as *sensitive periods*, then the child's development may be stunted as it were, from one line to another (Eveleth and Tanner 1990). As can be seen from the figure, young children and adolescents are particularly susceptible to environmental conditions. The return of adequate nutrition following a period of deprivation may restore normal length through catch-up growth. If conditions are inadequate for catch-up, individuals may approach normal adult height by an extension of the growing period by as long as several years. Prolonged and severe deprivation results in stunting, or a reduction in adult size (Steckel 1995). The solid line in Figure 1 illustrates this. Suppose that environmental circumstances are bad in the years immediately after birth, then the height increase in that period is stunted. The reduction in height can be recovered if conditions become more favourable in the next couple of years, but not completely: the surface below the solid line at the left is smaller than the surface below the thick solid line in the same period. The same applies for an adverse shock in environmental circumstances in the sensitive period of adolescence. Here height increments may become smaller too, and the reduction can be regained afterwards if things turn to the better by an extension of the period of growth.

The figure further illustrates the importance and the sensitivity of the age of measurement. Individuals measured at the age of twenty instead of nineteen may easily gain an additional 2-3 cm in height, cf. Section 5. This observation explains in part the finding of Baten (2000) that if the individuals are measured after having reached their final height, then the environmental circumstances of the first years after birth have the stronger influence.

3. The empirical model

Let H_t^τ be the average height of conscripts at age τ of the cohort measured in year t, which is observed from $t = 1, \ldots, T$. The attained height at age τ is by definition equal to the increments in stature from the year of birth

$$H_t^\tau \equiv \nabla H_t^\tau + \nabla H_t^{\tau-1} + \ldots + \nabla H_t^1 + \nabla H_t^0, \tag{1}$$

where $\nabla H_t^{\tau-i} \equiv H_t^{\tau-i} - H_t^{\tau-i-1}$ is the increment in height of the cohort of conscripts measured in year t between age $\tau - i$ and $\tau - i - 1$, $i = 1, \ldots, \tau$ and $\nabla H_t^0 (\equiv H_t^0)$ is the height at birth. We assume that the (unobserved) increments in height depend linearly on income Y, say, or

$$\nabla H_t^{\tau-i} = \alpha_{ti} Y_{t-i} + \varepsilon_{t-i}, \tag{2}$$

where ε_{t-i} is an error term. Of course, the framework can easily be extended to allow for other variables or more than one explanatory variable. Substituting Equation (2) into (1) gives

$$H_t^\tau = \sum_{i=0}^{\tau} \alpha_{ti} Y_{t-i} + \sum_{i=0}^{\tau} \varepsilon_{t-i} \equiv \alpha_t(L) Y_t + \epsilon_t, \tag{3}$$

where L is the lag operator $LY_t = Y_{t-1}$ and $\epsilon_t \equiv \sum_{i=0}^{\tau} \varepsilon_{t-i}$ is a moving average error expression. The matrix polynomial $\alpha_t(L)$ captures the velocity of growth: α_{ti} is relatively higher in the sensitive periods of the process of growth. As the subscript t indicates, the velocity of growth need not necessarily be time-invariant. Consequently, the lag pattern in our height model may change over time.

Since the height series is observed from $t = 1, \ldots, T$, the height-income relation of Equation (3) cannot be estimated without making further assumptions: we only have T observations to estimate $T \times (\tau + 1)$ parameters. Brinkman *et al.* (1988) make two additional assumptions:

(i) the curve of growth does not shift in time: $\alpha_t(L) = \alpha(L)$;
(ii) the growth curve can be modelled by an appropriate polynomial lag for the matrix polynomial $\alpha(L)$.

Under these assumptions Equation (3) simplifies to the familiar model

$$H_t^\tau = \alpha(L)Y_t + \epsilon_t. \tag{4}$$

The first assumption allows Brinkman *et al.* to assign weights to different ages that affect height: the Yearly Age- and Sex-Specific Increase in Stature (YASSIS), our $\alpha(L)$. They estimate the YASSIS terms by a third degree polynomial lag. Coll (1998) simplifies their method by assigning a weight scheme with weights fixed for a number of years. By this he avoids the polynomial lag. Baten (2000) observes that the form of the second assumption does not generate statistically significant differences in outcomes.

4. Method

Rather than estimating econometric models of height, we look for evidence of a change in the lag pattern by calculating correlation coefficients between height and some income and nutrition measures over different windows. To avoid spurious trend correlation, we first calculate deviations from trend, *i.e.* cycle components. We apply the Hodrick-Prescott (HP) filter to detrend our series, a standard method in the business cycle literature to remove trend movements. This method has withstood the test of time and the fire of discussion remarkably well, and is likely to remain one of the standard methods for detrending (Ravn and Uhlig, 2002).

The detrending method works as follows. Assume that an observed time series y_t in natural logarithms can be decomposed into a trend (or growth) component τ_t and a cycle component c_t

$$y_t = \tau_t + c_t. \tag{5}$$

The HP filter removes a smooth trend τ_t from some given series y_t by solving

$$\min_{\tau_t} \sum_{i=1}^{T} \left((y_t - \tau_t)^2 + \lambda((\tau_{t+1} - \tau_t) - (\tau_t - \tau_{t-1}))^2 \right). \tag{6}$$

The residual $y_t - \tau_t$ is then commonly referred to as *cycle component.*

The smoothing parameter λ, which penalizes the acceleration in the trend relative to the cycle component, depends in the frequency of observations. For quarterly data λ is typically set to 1600. Recently, Ravn and Uhlig (2002) have demonstrated that $\lambda = 6.25$ is preferable for annual data. Below we employ their recommendation.

A typical property of trend filters like the HP filter is the sensitivity to the first few and the last few observations, the so-called *end value* problem. Baxter and King (1999) recommend dropping at least three observations from either end of the sample when using the HP filter on annual data. We follow their advice and ignore the first three and the last three observations in the computation of correlation coefficients.

To search for evidence of a change in the lag pattern between height and income and nutrition measures, we calculate correlation coefficients between cycle components of height and (lagged) cycle components of various income and nutrition measures for rolling thirty one-year windows. For each window we calculate the correlation between the cycle components in height and a typical income or nutrition measure. Then we lag the series of the measure by one year and calculate the correlation coefficient again. We continue taking lags up to and including 21 years, the examination age plus one, capturing the year before birth.

In the correlation figures below we only show significant correlation coefficients. It is well-known that the HP filter may create spurious correlations between two uncorrelated I(1) series (Harvey and Jaeger, 1993). Therefore standard confidence intervals for correlation coefficients which are based on the null hypothesis of uncorrelated white noise do not apply here. We calculated bootstrapped critical values for correlation coefficients between HP filtered series using 1000 replications. We generated two random series, cumulated these into random walks, calculated cycle components with the HP filter ($\lambda = 6.25$), and the correlation coefficient. The full series of 1000 correlation coefficients is then ordered which produces the critical value as the maximum of the values (in absolute value) that correspond to the 5% and the 95% values of the distribution.

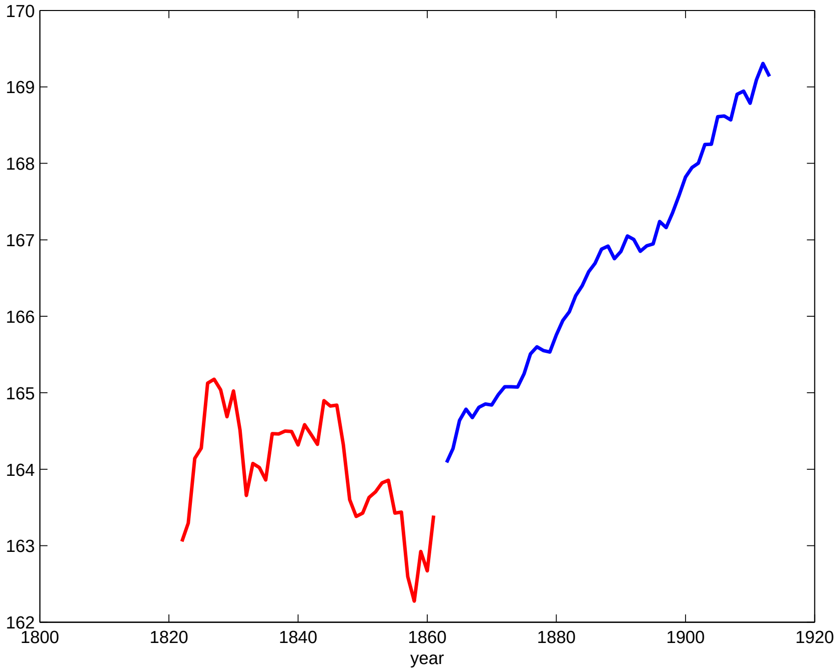
5. Data

Height

We use the median height of Dutch conscripts series analysed by Drukker and Tassenaar (1997). Shifts in the year of measurement complicate the analysis of height of conscripts data. In 1861 the Dutch government changed the military laws because of the rising percentage of undersized conscripts. From 1863 on, the age of recruitment was raised from 19 to 20. Figure 2 shows the median height series. The change in the recruitment age resulted in a height increase of 2-3 cm. We corrected the pre-1862 figures by adding 3 centimeters to the original heights. In our computations below we only use the second part of the sample, the 1863-1913 period. This choice does not require us to make an ad-hoc adjustment in the height series.[1] Besides, we work with better quality time series, since the second part

1. As noted by Mandemakers and Van Zanden (1993) conscripts were measured in the Spring before 1892, and in the Fall of the year thereafter, resulting in an increase in the average age of measurement from approximately $19\frac{3}{4}$ years to $20\frac{1}{4}$ years. In our empirical analyses below we do not correct for this increase in measurement age. Some experimentation has shown that correction affects the quantitative outcomes, but does not change our main, qualitative conclusion.

Figure 2: Average heights of conscripts at age 19 (before 1862) and at age 20 (after 1862); cm



Source: Drukker and Tassenaar (1997)

of the height series is more reliable than the first part, as can be seen from the difference in the fluctuations in the series.[2]

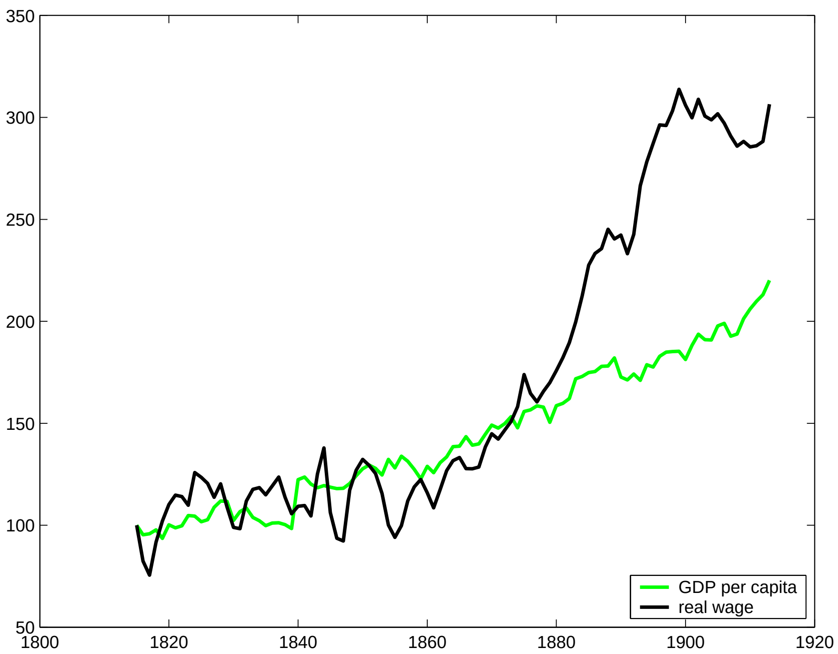
The median stature of Dutch conscripts increased substantially and almost uniformly after 1860, even if the gains during the initial decade (1863-1870) were only a recovery to previous levels. Average height reached its nadir in 1857 (Tassenaar 2000) after a period of decline starting in the 1840s. The phenomenon of decreasing heights in European countries in the early-industrial revolution era is known as the "shrinking paradox" (Komlos 1998). In the 1860s height recovered somewhat in comparison to the late fifties, but stayed well below previous levels. The upward trend started with the cohorts of the 1870s born in the 1850s. In the early 1880s median height surpassed levels reached during the first half of the nineteenth century. Thereafter it rose continuously. Until WW I only very short cyclical setbacks can be observed.

2. Note that our income and nutrition measures derived from Smits *et al.* (2000) described below share this property.

Income measures

We distinguish two income measures: GDP per capita and real wage, see Figure 3. Both income measures originate from Smits *et al.* (2000). For a general overview of the economic history of the Netherlands in the nineteenth century see Van Zanden and Van Riel (2000). The discontinuity around 1840 in the GDP per capita series is probably caused by improper accounting for the separation of Belgium.[3] Apart from that their estimates are quite plausible and indicate that real GDP per capita had an almost constant growth rate from the end of the Napoleonic era until World War I. The development of real wages is slightly erratic in the first half of the nineteenth century, fluctuating around a more or less constant level. In the middle of the nineteenth century nominal wages started to rise after at least two centuries of stagnation. From around 1870 onwards, the Netherlands entered the stage of modern economic growth. Real wages accelerated until the end of the century, interrupted only by recessions in 1876–1877 (the onset of the Agricultural Depression) and 1888–1890. Real wages fell in the first years of the twentieth century partly due to an increase in the general price level, but rose sharply at the eve of World War I.

Figure 3: GDP per capita and real wages; index numbers 1815=100 and 1913=100, respectively



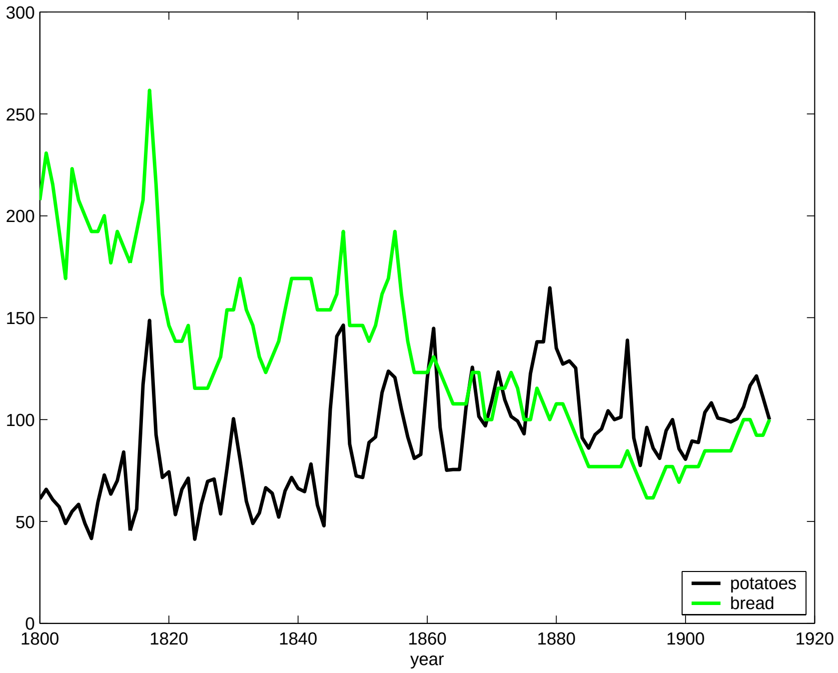
Source: Smits *et al.* (2000)

3. The separation took place *de facto* in 1830, but *de jure* in 1839 when the province of Limburg was split up.

Nutrition measures

Detailed information on nutrition in the Netherlands in the nineteenth century is not available. Unfortunately, the daily caloric intake and protein series of Knibbe (2001) are not long enough for our purposes. Therefore we use prices of two main ingredients of the nineteenth century diet: potatoes and bread.[4] Well into the nineteenth century the price of potatoes had a direct, inverse relation to consumption. For the price of bread the situation is slightly more complex, since at least two varieties of bread were consumed, wheat bread and rye bread, the latter being an inferior good. Figure 4 shows our nutrition measures.

Figure 4: Price of potatoes, and price of bread



Source: Smits *et al.* (2000)

The potato price follows the general pattern of prices of agricultural goods. Until 1880 prices of agricultural goods generally became higher, thereafter prices especially of arable products decreased: the Agricultural Depression. In the forties, fifties and sixties the potato price fluctuated heavily because of an almost endemic plant disease (phytophtera).[5] The potato price fell in the early 1880s and gradually became higher in the beginning of the twentieth century.

4. We analysed some other prices, including meat, milk, wheat, and rye. See Appendix B.

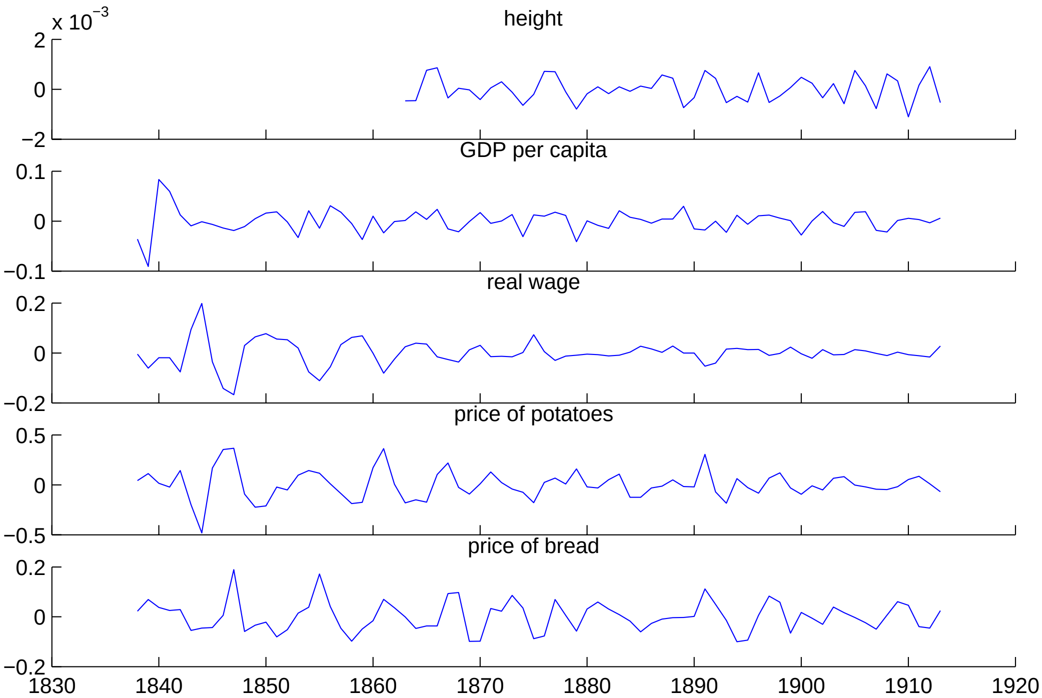
5. This might also be a sign of the poorer quality of the price data in general and in the first half of the nineteenth century in particular.

The price of bread had a downward tendency during the greatest part of our sample. The main reason for this downward tendency is technological progress which led to improvements in the milling process and a reduction in transport costs. In addition, institutional reforms like the abolishment of a levy on milling (in 1855) and huge inflows of grain especially from North America (from the early 1870s onwards) had a mitigating effect on the price of bread. At the end of the nineteenth century the bread price started to pick up, in line with the pattern in the prices of agricultural goods.

6. Results

Figure 5 shows the cycle components in height and our income and nutrition measures, which are calculated by applying the HP-filter on the natural logarithms of the series. We clearly observe cyclical patterns, although the deviations from trend in case of the height series are smaller than the cycle components in the other series.

Figure 5: Cycle components



The next four figures show the correlation outcomes between cycle components of height and our income and nutrition measures, for moving thirty one-year windows with lags up to 21 years respectively. As mentioned earlier we only show significant correlation outcomes (at the 10% level). In all figures the first window refers to the 1866–1896 period. Then the window is moved by one year, *i.e.*, we look at 1867–1897, and repeat the analysis calculating the (significant) correlation coefficients between the cyclical components in heights and the (lagged) cyclical components in GDP per capita (`window=2`). We keep on moving the window until the final year of the window coincides with the final observation in our sample. The final window, the 15th, is the 1880–1910 period.

A puzzling property of Figures 6–9 is the occurrence of negative correlation values at certain lags in the height-income measures graphs surfaces and positive correlation outcomes at certain lags in the height-nutrition measures graphs.[6] The canyon in the height-real wage graph, Figure 7, and the mountain in the height-price of bread graph, Figure 9, at the fourth lag are typical examples. The straightforward interpretation of favourable economic conditions four years before examination exerting a negative influence on height is clearly not true. A candidate explanation might be the following one. The correlation coefficient between two series that are perfectly synchronised is equal to one. However if we calculate correlations between one series and another series that is lagged up to the duration of the full cycle, the correlations fluctuate between 1 and -1. Another explanation runs as follows.[7] Suppose that an economy is hit by a recession two years before a cohort of conscripts is measured. The mean height of this cohort will be negatively affected. Therefore, we would expect a positive correlation coefficient between height and the income measures at the second lag. If the economic conditions were beneficial around four years or half a business cycle earlier, in a less growth sensible period, negative correlations outcomes could result at higher lags.

6. We drop the expression cycle components or deviations from trend where it should not cause any confusion.

7. We thank a referee for this suggestion.

Figure 6: Height and (lagged) GDP per capita (10% level)

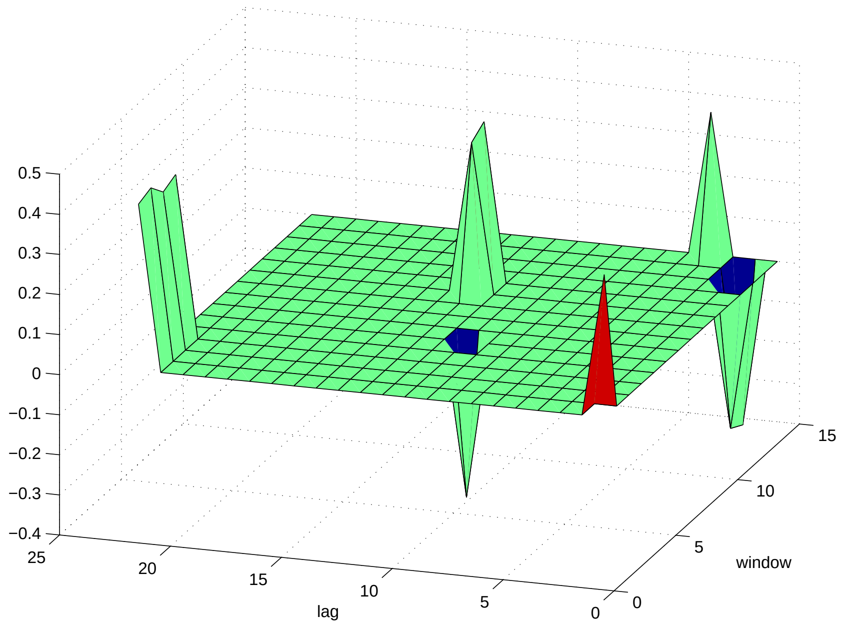


Figure 7: Height and (lagged) real wage (10% level)

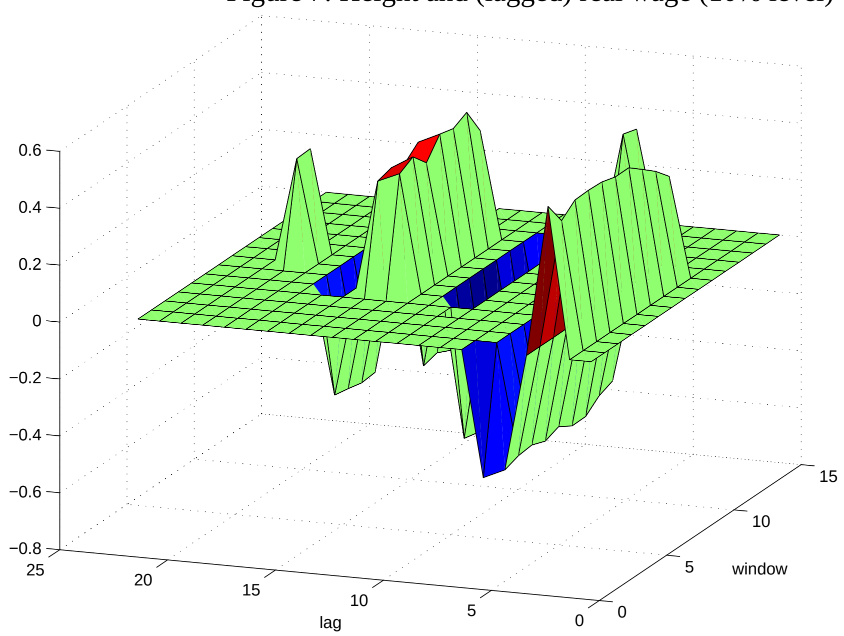


Figure 8: Height and (lagged) potato price (10% level)

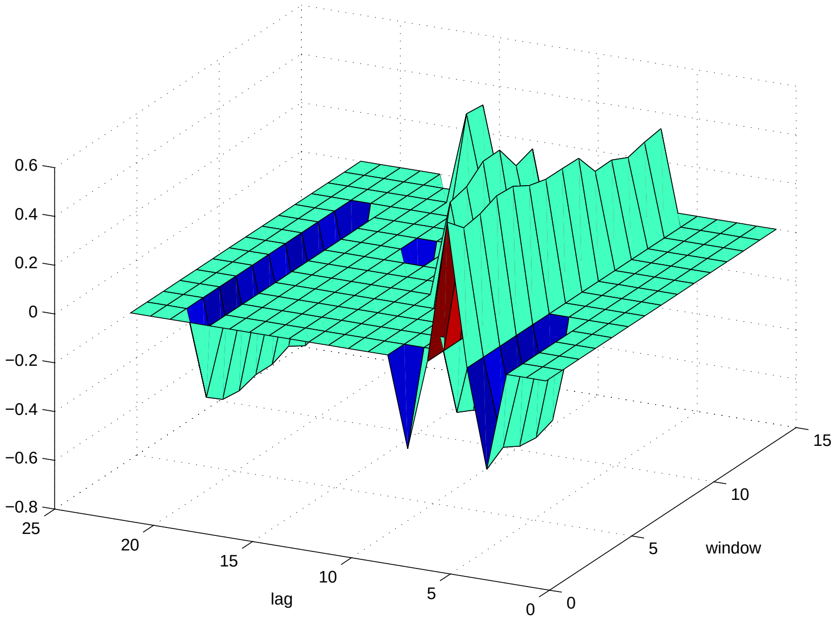
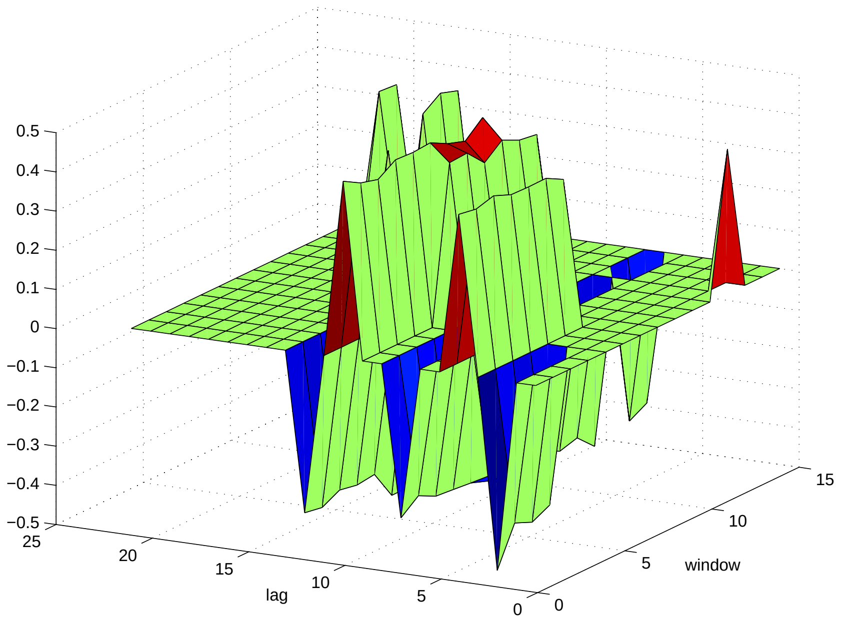


Figure 9: Height and (lagged) bread price (10% level)



Taking into account that in the process of growth a person cannot become smaller, we do not feel too uncomfortable focusing on positive values of the correlations between height and the income measures and negative values for the correlations between height and the prices of potatoes, bread and meat. With these caveats the correlation surfaces of Figures 6–9 allow the following observations.

- The correlation between height and real wages stands out more clearly than the one between height and GDP per capita. This outcome does not come as a surprise, because real wage have a more direct link to consumption and hence the standard of living. The difference between our nutrition measures is less clear. The potato price seems more informative in terms of significant correlation with height than the bread price.

- If the lag pattern between height and its determinants is time-invariant, we expect the growth sensitive periods just after birth and the adolescence growth spurt around the age of 17-18 years (Oppers, 1963) to show up in the graphs. This corresponds to hills (canyons) in the height-income (height-nutrition) figures at the lags of 18-21 years and 2-3 years in all windows. Although both the real wage and the potato price (and to a lesser degree the bread price) are correlated with height at lags corresponding to the childhood growth spurt and the adolescence growth spurt in some windows, the correlations are not significant throughout the sample, *i.e.* in at all windows. The hills (canyons) corresponding to the childhood and adolescence growth spurt periods disappear in the later windows or the end of our sample. We interpret this as evidence against time-invariant lag patterns.

- The adolescence growth spurt is more apparent in the correlation surfaces than the early childhood growth spurt. In addition, we do not find signs of a significant birth year effect, although pre-birth conditions show up in the first four windows of the height-GDP per capita correlations. This observation is in line with one of the conclusions of Baten (2000): the further away the time of measurement, the higher the possibility to catch-up after a period of stunted growth caused by a deterioration in the standard of living. The period for adolescents to catch up after a period of stunted growth may well be too short.

- The significant correlation outcomes at a lag of seven year between height and the bread price and the potato price, the 12-year lag for the bread price, and the lags of 12-13 years of the real wage are hard to reconcile with the velocity curve of growth. Even the youth growth spurt, another finding of Oppers (1963), cannot help us here, since that refers to youngsters at the age of 10-11 years, or lags of 9-10 years.

So, we conclude that the correlation figures do indeed give an indication of a change in the lag patterns in the relationship between height and some income and nutrition measures, even for the rather short period and small number of rolling windows analysed here.

7. Conclusion

The aim of this paper was to explore the dynamic relationship between height and its explanatory variables. Empirical height studies typically assume that the velocity of growth is fixed in time. We showed that this assumption is invalid and provided evidence for changing lag patterns in a recently published data set on 19th century for the Netherlands.

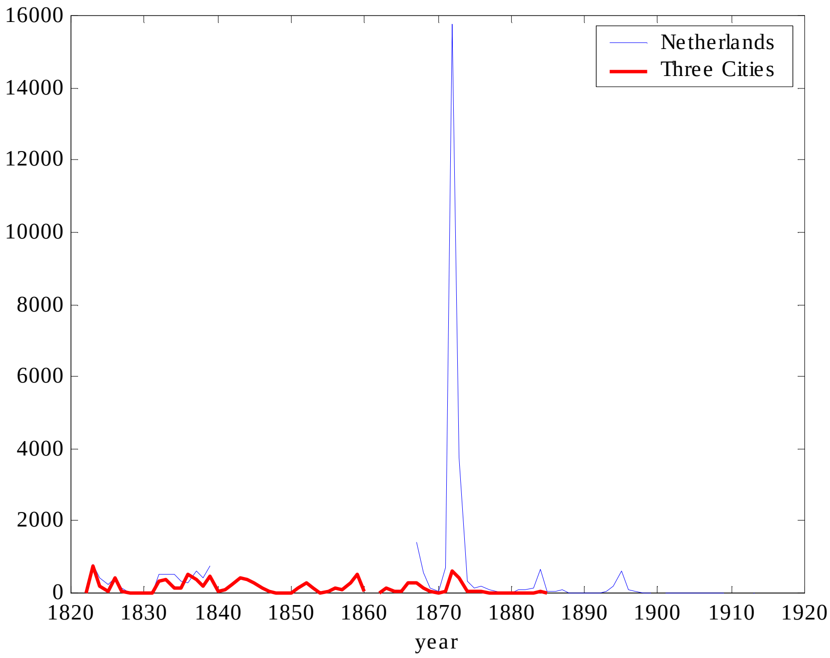
To assess the significance of changing lags we calculated correlation coefficients between detrended components in height and some income and nutrition measures over moving windows. We found that the real wage was the most informative income measure and the price of potatoes the ‘best’ nutrition measure. The correlation between these two measures and height was strongest at lags corresponding to two well-known sensitive growth periods, early childhood and adolescence, the latter being the most pronounced.

We did indeed find evidence of a change in the lag pattern between detrended height and income and nutrition measures. This does not imply that the ’standard’ method of estimating height models assuming a time-invariant velocity growth curve is not justified any longer. For the period under consideration, the second half on the nineteenth century, standard estimation of heights in the Netherlands may not lead to serious errors. However more research is needed, not only covering other countries and longer periods but also the actual estimation of dynamic height models over different subperiods and/or with time-varying lag parameters, before the assumption of time-invariant lag patterns is to be dismissed completely.

A. Appendix. Height and smallpox

The relationship between smallpox and height received a lot of attention too. Voth and Leunig (1996) concluded that smallpox had a significant negative impact on height in Britain. This conclusion was questioned by *e.g.* Razzell (1998), Baten and Heintel (1998) and Oxley (2002). The effect of smallpox on height in the Netherlands has not been studied before. The reason might be the typical pattern of smallpox in the Netherlands. Figure 10 shows the number of smallpox victims in the Netherlands and in the three cities Amsterdam, Rotterdam and the Hague. Our smallpox data come from Rutten (1997).

Figure 10: Smallpox victims in the Netherlands and three cities (Amsterdam/Rotterdam/the Hague)



Source: Rutten (1997)

Smallpox were prevalent during most of the 19th century. Vaccination began in the beginning of that century, so smallpox was more or less under control. The exception to the rule is the smallpox pandemic of 1870-1872, with over 20,000 victims, for the greater part young children in the age of one to three years. A striking fact is that the three largest cities in the Netherlands, Amsterdam, Rotterdam and the Hague were not severely hit by the smallpox outburst. Mortality was highest in the provinces Utrecht, North-Holland south of the river Y and South-Holland north of the river Meuse, the area now known as Randstad and the Green Heart. Rutten (1997, Section 11.3) lists a number of explanations. First, mortality of smallpox was highest in areas where vaccination was optional and lowest where vaccination was compulsory. Secondly, population density plays an important role and thirdly, the distance to smallpox centres at home and abroad. Finally, factors in the biological environment were important.

Smallpox cannot be treated in the same way as the other variables distinguished in this paper. The smallpox pandemic in 1870-1872 may have resulted in the stagnation in height increases starting in the late 1880s until the mid-1890s. So, the Dutch data do not support the conclusion of Voth and Leunig (1996) that smallpox had a serious negative effect on height. The smallpox outbreak in the beginning of the 1870s may have led though to a stagnation in height increases in the late 1880s till the mid-1890s.

Appendix B. Correlation between height and some other prices

Figure 11: Price of wheat, barley, buckwheat and rye

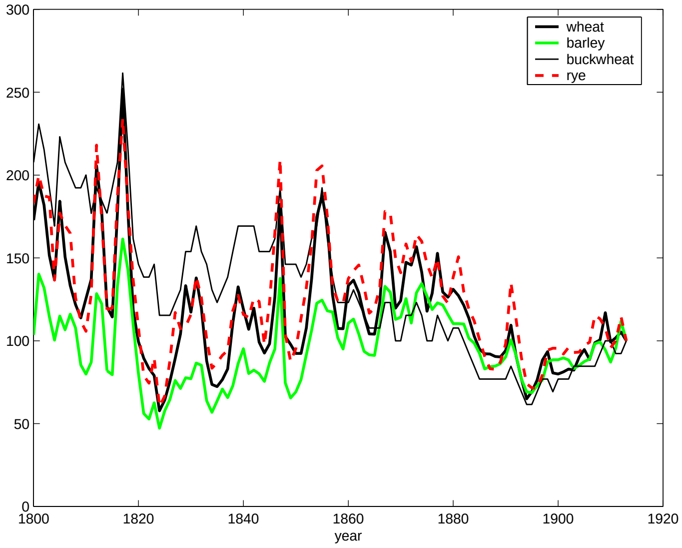


Figure 12: Price of meat and milk

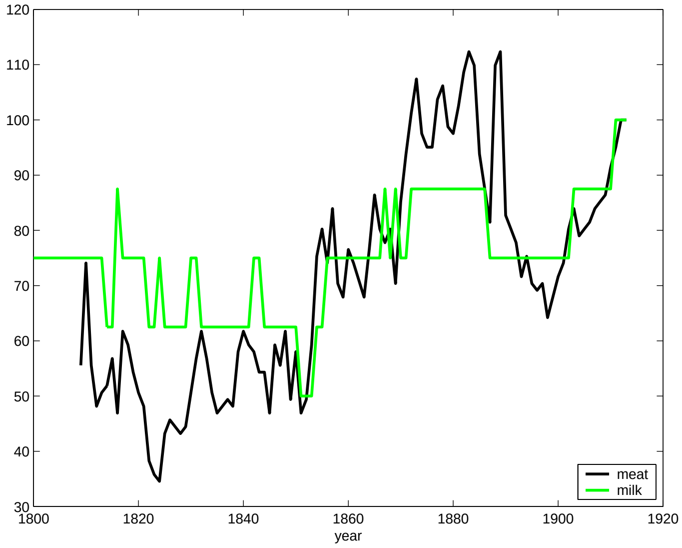


Figure 13: Height and (lagged) wheat price (10% level)

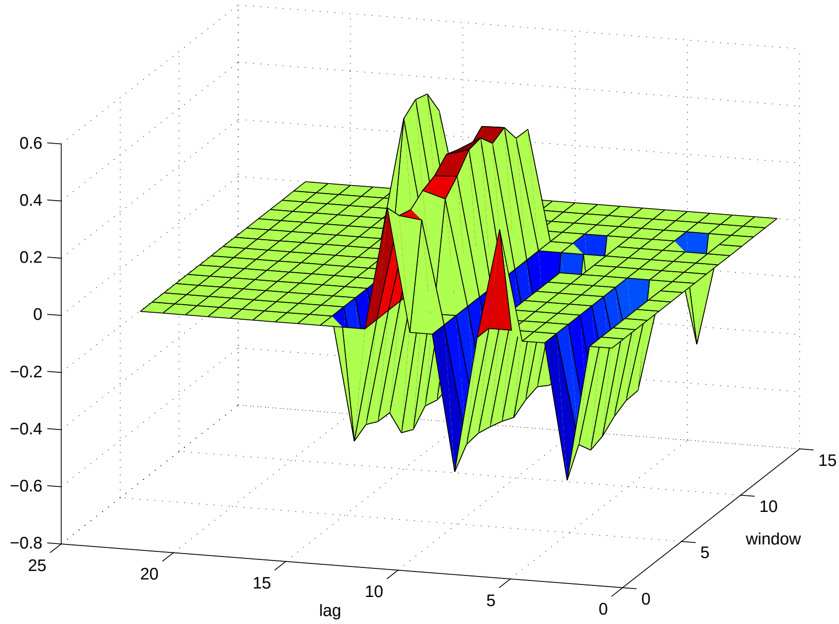


Figure 14: Height and (lagged) buckwheat price (10% level)

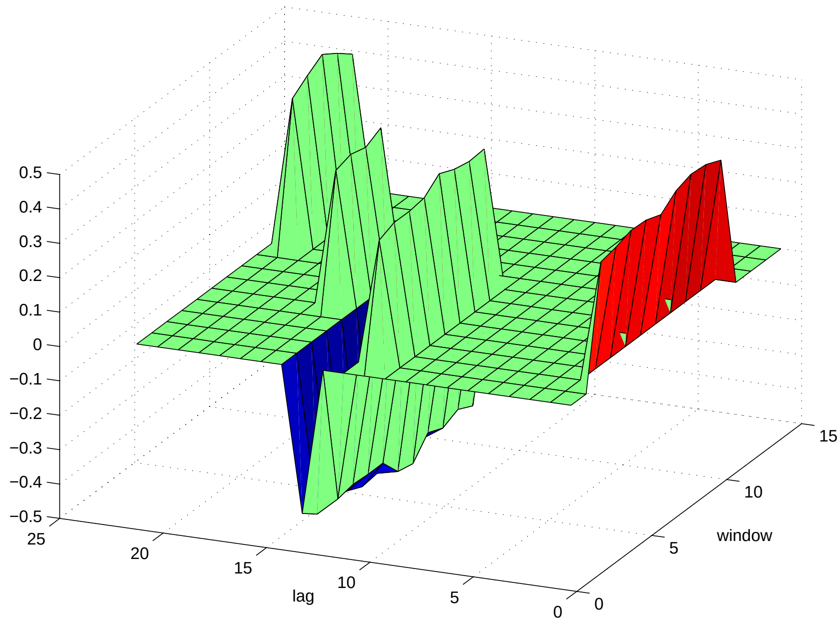


Figure 15: Height and (lagged) barley price (10% level)

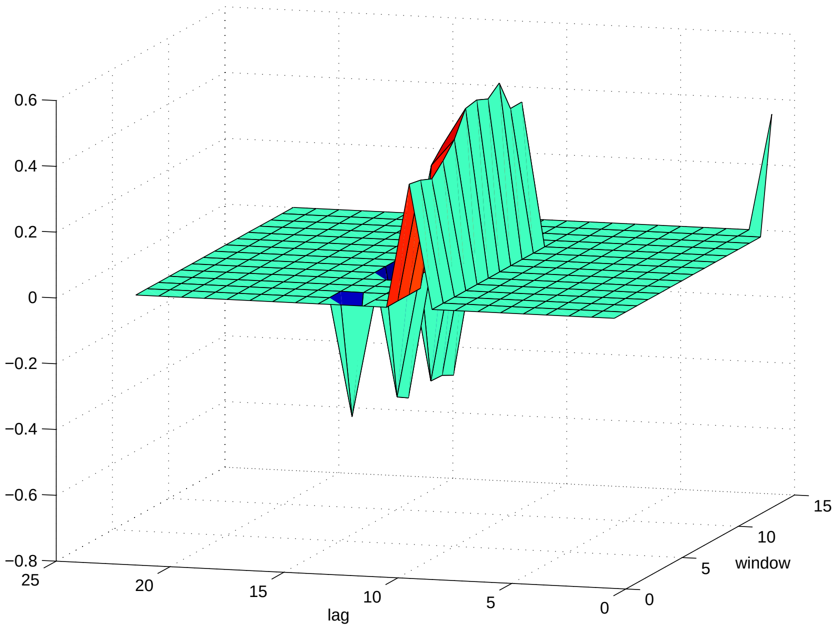


Figure 16: Height and (lagged) rye price (10% level)

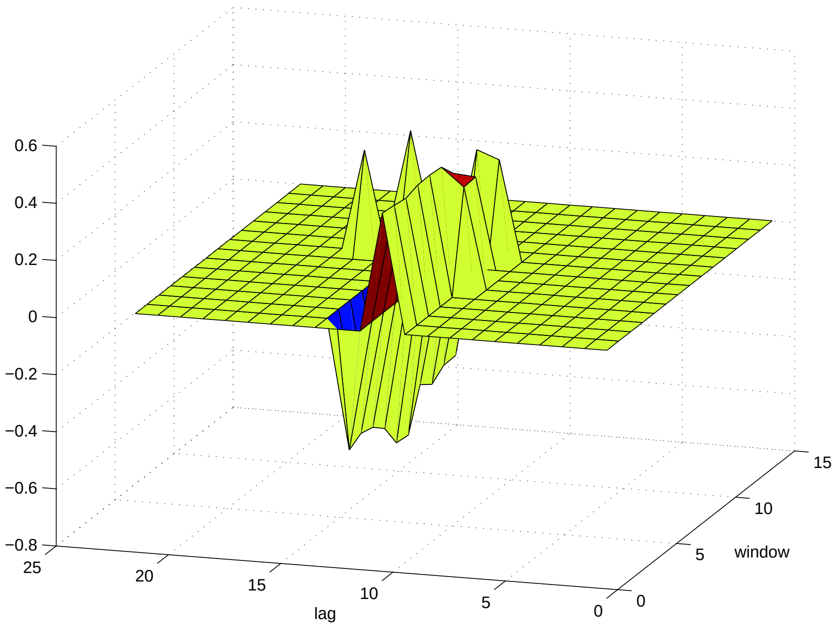


Figure 17: Height and (lagged) meat price (10% level)

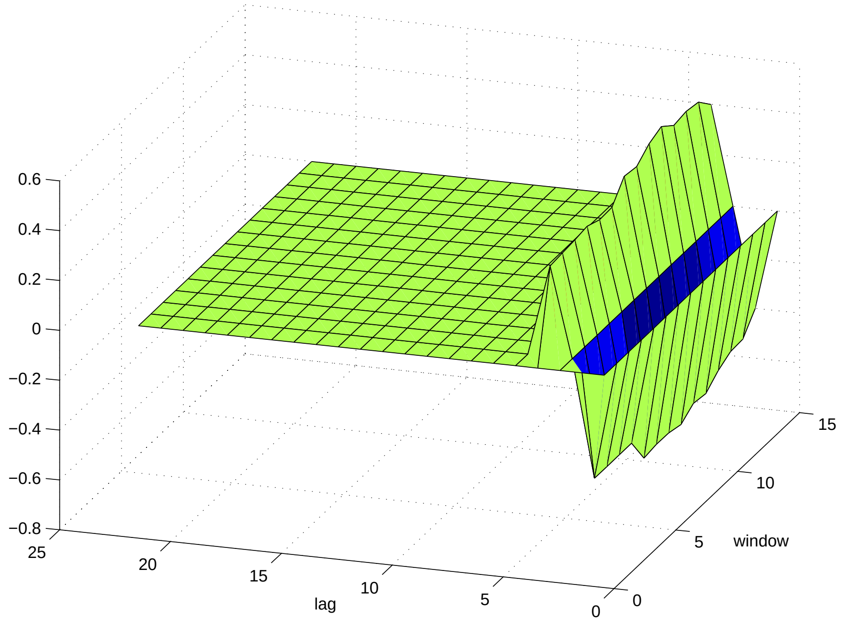
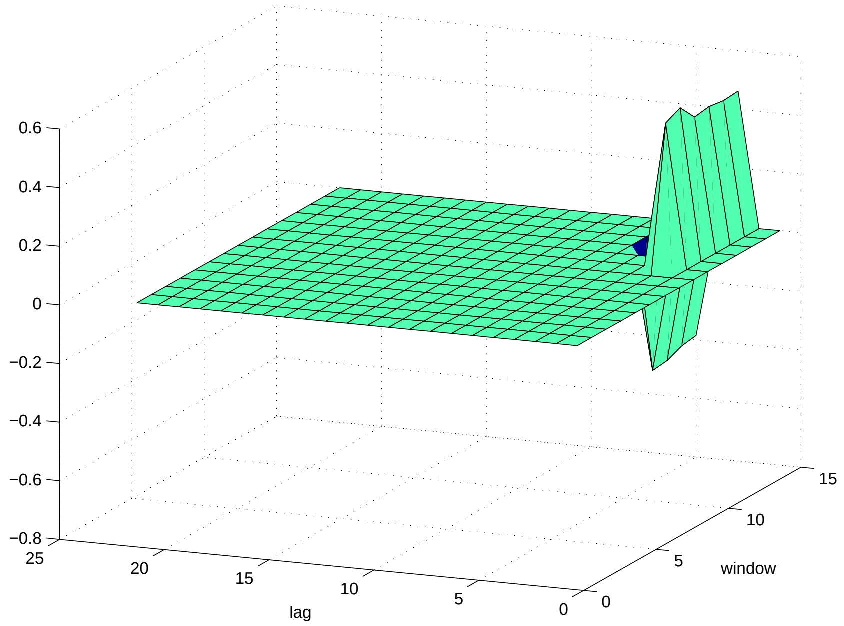


Figure 18: Height and (lagged) milk price (10% level)



References

Baten, J. (2000), "Height and real wages: An international comparison", *Jahrbuch für Wirtschaftsgeschichte*, **11**, 61–76.

Baten, J. and M. Heintel (1998), "Smallpox and nutritional status in England, 1770-1873: On the difficulties of estimating historial heights", *Economic History Review*, **51**, 360–371.

Baten, J. and J.E. Murray (2000), "Heights of men and women in 19th-century Bavaria: economic, nutritonal, and disease influences", *Explorations in Economic History*, **37**, 351–369.

Baxter, M. and R.G. King (1999), "Measuring business cycles: approximate band-pass filters for economic time series", *Review of Economics and Statistics*, **81**, 575–593.

Brinkman, H.J., J.W. Drukker, and B. Slot (1988), "Height and income: a new method for the estimation of historical national account series", *Explorations in Economic History*, **25**, 227–264.

Coll, S. (1998), "The relationship between human physical stature and GDP (some experiments with European time series)", in J. Komlos and J. Baten, editors, *The Biological Standard of Living in Comparative Perspective*, Franz Steiner Verlag, Stuttgart, 384–407.

Craig, L.A. and T. Weiss (1998), "Nutritional status and agricultural surpluses in the Antebellum United States", in J. Komlos and J. Baten, editors, *The Biological Standard of Living in Comparative Perspective*, Franz Steiner Verlag, Stuttgart, 190–207.

Drukker, J.W. and P.G. Tassenaar (1997), "Paradoxes of modernization and material well-being in the Netherlands during the 19th century", in R.H. Steckel and R. Floud, editors, *Health and Welfare during Industrialization*, Chicago University Press, Chicago, IL, 331–379.

Eveleth, P.B. and J.M. Tanner (1990), *Worldwide Variation in Human Growth*, 2nd edition, Cambridge University Press, Cambridge.

Floud, R., K. Wachter, and A. Gregory (1990), *Height, Health and History: Nutritional Status in the United Kingdom*, Cambridge University Press, Cambridge.

Fredriks, A.M., S. van Buuren, R.J.F. Burgmeijer, J.F. Meulmeester, R.J. Beuker, E. Brugman, S.P. Verloove-Vanhorick M.J. Roede, and J.M. Wit (2000), "Continuing positive secular growth change in the Netherlands, 1955-1997", *Pediatric Research*, **47**, 316–323.

Haines, M.R. (1998), "Health, height, nutrition, and mortality: Evidence on the 'Antebellum Puzzle' from Union army recruits for New York State and the United States", in J. Komlos and J. Baten, editors, *The Biological Standard of Living in Comparative Perspective*, Franz Steiner Verlag, Stuttgart, 155–175.

Harvey, A.C. and A. Jaeger (1993), "Detrending, stylized facts, and the business cycle", *Journal of Applied Econometrics*, **8**, 231–247.

Hodrick, R.J. and E.C.Prescott (1997), "Postwar U.S. business cycles: An empirical investigation", *Journal of Money, Credit, and Banking*, **29**, 1–16.

Knibbe, M. (2001), "De ontwikkeling van de voedselsituatie in Nederland, 1851-1950", *NEHA-Jaarboek voor economische, bedrijfs- en techniekgeschiedenis*, **64**, 200–226.

Komlos, J. (1989), *Nutrition and Economic Development in the Eighteenth-Century Habsburg Monarchy: An Antropometric History*, Princeton University Press, Princeton, NJ.

Komlos, J. (1998), "Shrinking in a growing economy? The mystery of physical stature during the Industrial Revolution", *Journal of Economic History*, **58**, 779–802.

Komlos, J. and J. Baten, editors (1998), *The Biological Standard of Living in Comparative Perspective*, Franz Steiner Verlag, Stuttgart.

Komlos, J., J.M. Tanner, P.S.W. Davies, and T. Cole (1992), "The growth of boys in the Stuttgart Carlschule, 1771-1793", *Annals of Biology*, **19**, 139–152.

Ljung, B.-O., A. Bergsten-Brucefors, and G. Lindgren (1974), "The secular trend in physical growth in Sweden", *Annals of Human Biology*, **1**, 245–256.

Mandemakers, C.A. and J.L. van Zanden (1993), "The heights of conscripts and national income: apparent relations and misceptions", *Explorations in Economic History*, **30**, 81–97.

Mosk, C. (1996), *Making Health Work. Human Growth in Modern Japan*, University of California Press, Berkeley, Los Angeles, London.

Oppers, V.M. (1963), *Analyse van de acceleratie van de menselijke lengtegroei door bepaling van het tijdstip van de groeifasen*, PhD thesis, University of Amsterdam, Amsterdam.

Oxley, D. (2002), "Smallpox and height: a histopathological approach", mimeo, University of New South Wales, Sydney, Australia.

Ravn, M.O. and H. Uhlig (2002), "On adjusting the Hodrick-Prescott filter for the frequency of observations", *The Review of Economics and Statistics*, **84**, 371–380.

Razzell, P. (1998), "Did smallpox reduce height?", *Economic History Review*, **51**, 351–359.

Rutten, W.J.M.J. (1997), *'De vreselijkste aller harpijen': pokkenepidemieën en pokkenbestrijding in Nederland in de achttiende en negentiende eeuw: een sociaal-historische en historisch-demografische studie*, PhD thesis, Wageningen University, Wageningen.

Smits, J.P., E. Horlings, and J.L. van Zanden (2000), *Dutch GNP and its components, 1800-1913*, Number 5 in Groningen Growth and Development Centre Monograph Series, Groningen Growth and Development Centre, Groningen.

Steckel, R.H. (1995), "Stature and the standard of living", *Journal of Economic Literature*, **XXXIII**, 1903–1940.

Tanner, J.M. (1981), *A History in the Study of Human Growth*, Cambridge University Press, Cambridge, UK.

Tanner, J.M. (1989), *Foetus into Man: Physical Growth from Conception to Maturity*, 2nd edition, Castlemead Publications, Ware.

Tassenaar, P.G. (2000), *Het Verloren Arcadia. De Biologische Levensstandaard in Drenthe, 1815-1860*, Labyrint Publication, Capelle aan de IJssel.

Voth, H.J. and T. Leunig (1996), "Did smallpox reduce height? Stature and the standard of living in London, 1770-1873", *Economic History Review*, **44**, 541–560.

Wit, J.M., S.M.P.F. de Muinck Keizer-Schrama, and H.A. Delemarre van de Waal, editors (1999), *Groeistoornissen*, Elsevier, Maarssen.

Woitek, U. (2003), "Height cycles in the 18th and 19th centuries", *Economics and Human Biology*, **1**(2), 243–257.

Zanden, J.L. van and A. van Riel (2000), *Nederland 1780–1914. Staat, instituties en economische ontwikkeling*, Balans, Amsterdam.